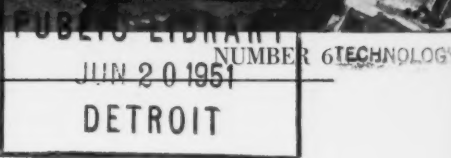


National Bureau of Standards

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NUMBER 6 TECHNOLOGY

DETROIT

R-F Dielectric Standards

To aid in determining the properties of dielectrics and their dependence on frequency, temperature, and humidity, the National Bureau of Standards has established radio-frequency standards for dielectric measurements. For solid dielectric specimens, dielectric constant and power factor calibration services are now available in the frequency range from 10 kc to approximately 600 Mc. Somewhat more limited calibration services are also offered for gases and liquids.

In recent years information on the properties of dielectric materials has become increasingly important not only to designers and manufacturers of electronic equipment but also to the scientist who is studying molecular structure. The new standards and services provided by the Bureau are expected to be of material assistance in these fields.

The NBS technique for evaluating dielectric properties employs a disk-shaped capacitor made from the material to be investigated. The complex dielectric constant of this capacitor is conveniently measured by bridge or resonance methods. Special micrometer electrode systems, consisting essentially of two plates which form a variable capacitor, are used. They are precision instruments constructed so that the circular electrodes are plane parallel and near optical flatness. One electrode is insulated by a quartz disk, while the movable or grounded electrode is attached to a holder by metal bellows so arranged that there are no sliding contacts. The position of the movable electrode is

accurately controlled by a micrometer, and the capacitance of the entire system is calibrated against an incremental precision capacitor. The structure supporting the movable electrode forms an effective shield for the electrode system.

The NBS micrometer electrode system is used in conjunction with conventional bridges or resonance indicating devices. The dielectric specimen is inserted between the electrodes, and the bridge is balanced or the circuit resonated. The specimen is then removed, and the spacing between the electrodes is reduced until the bridge rebalances or the circuit reresonates. The dielectric constant is determined from the capacitance corresponding to this reading on the micrometer dial and the capacitance corresponding to the micrometer dial when set to the known thickness of the specimen. This technique for determining the dielectric constant circumvents fringing errors and is known as the susceptance variation method. It is valid with commercially available bridges for frequencies up to approximately 300 Mc. Errors due to series inductance are reduced, becoming a function only of the change in length of the movable electrode, which is negligible for most values of capacitance.

At frequencies above 500 kc, the power factor and dielectric constant are usually determined most accurately by a resonance method. In this technique, the circuit including the electrode system and the specimen is resonated, and the voltage across the unknown is

recorded. The specimen is then removed, the circuit reresonated, and the voltage across the air capacitor is recorded. From these voltages and the known Q of the electrode system, the loss properties of the specimen are evaluated. Again, the dielectric constant is simply determined from the dial reading of the micrometer at the reresonant point and the corresponding calibrated capacitance.

This resonance technique is used over a wide frequency range and is particularly applicable at frequencies above 100 Mc. At these frequencies the inductor becomes a single turn; therefore a doubly reentrant resonant cavity (essentially a coaxial structure shorted at both ends with a variable gap in the center conductor) of either fixed or variable length is utilized. The test specimen occupies the gap between the reentrant posts. This again permits measurements without appreciable corrections for lead induction. The techniques used in the resonance method are equally applicable to reentrant cavity measurements. Resonant cavities are advantageous because Q 's of the order of 1,000 to 3,000 can be readily obtained, thus providing convenient voltage ratios even in the case of very low-loss specimen, such as polystyrene or quartz.

Q 's of this magnitude are not common at frequencies below 50 Mc. In this region, resonant circuits with normal values of Q have sensitivities hardly better than the power factor of low-loss materials. Therefore, it is necessary to resort to special circuitry in order to obtain low-loss measurements at these frequencies. A suitable circuit can be achieved by using a linear, stable negative resistance. When this resistance is connected in series with an inductor and a conventional micrometer electrode, it can be adjusted to cancel very nearly the resistance of the rest of the system, thus producing a resonant measuring system of extremely high Q . As a result, the losses in the system are primarily due to the



Apparatus used to measure the dielectric constant and power factor of materials such as polystyrene or quartz. The measuring unit (center foreground) consists of a negative resistance circuit yielding Q values of 100,000 at frequencies near 1 megacycles. The sample material is inserted in an electrode system (above operator's hand) which serves as a variable condenser, and a voltmeter (right) measures the voltage across this capacitor-electrode system. At the left is a high-frequency generator, and in the center a direct-current power supply.



TECHNICAL NEWS BULLETIN

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CHARLES SAWYER, *Secretary*

NATIONAL BUREAU OF STANDARDS
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specimen, thus enabling an accurate evaluation of its dielectric properties.

The circuit used is effectively a cathode follower with a capacitive load and increased grid-to-cathode capacitance. Under these conditions the real component of the input impedance has a large negative magnitude and can be adjusted by varying one of the circuit parameters. The large amount of negative feedback makes the circuit extremely stable and yields excellent linearity, because only very low amplitude signals are applied. Q 's of 100,000 have been obtained with an instability of only a few percent over a period of 10 minutes, with no detectable deviation from the normal resonance curve resulting from nonlinearity. These conditions make it possible to measure dissipation factors of the order of 10^{-5} to an accuracy of about 10 percent and, of course, lower losses (less than 10^{-5}) with less accuracy.

Studies are continuing in an effort to extend the frequency range of the negative-resistance system so that it may be used at any frequency up to those at which cavity methods become practical. Other work in progress is directed toward the adaptation of the system for measuring the dielectric constants of gases.

RATIO TO UNPLATED STEEL

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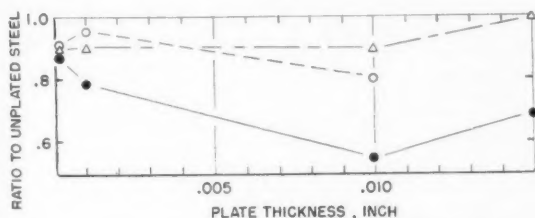
Plastic Deformation of Chromium-Plated Steel for Aircraft

Chromium plating, because of its hardness and ease of application, is widely used on all types of machine elements to protect softer metals from wear and to salvage worn or undersized parts. However, the advantages of chromium plating are sometimes offset by a reduction in the ability of the basis metal to deform plastically without breaking. To learn more about the effect of chromium plating on the plastic deformation of steels used in aircraft, Hugh L. Logan of the Bureau's Metallurgy Division has recently made a comprehensive study [1] of the mechanical properties of chromium-plated SAE 4130 steel. The results of this investigation, which was sponsored by the Bureau of Aeronautics, Department of the Navy, provide information of interest not only to aircraft manufacturers but also to a number of other industries that produce or utilize chromium-plated machine parts.

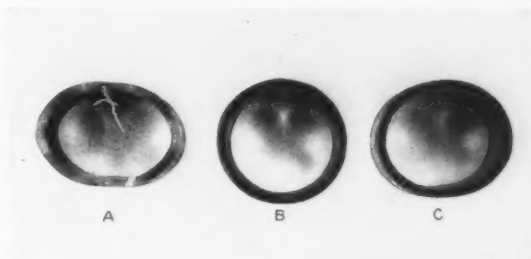
The NBS investigation included tensile, tensile impact, bending, and crushing tests of specimens prepared from rod and tubing of SAE 4130 chromium molybdenum steel heat-treated to a hardness of about 40 C Rockwell scale before the final machining. Some of the specimens were tested as machined, without plating; others were tested after plating to one or more thicknesses; and still others after both plating and subsequent baking at various temperatures up to 440° C. The effect of baking was of interest since the usual commercial practice is to bake chromium-plated steel articles at a temperature of 200° C for several hours after plating. Chromium was deposited from a bath containing 250 grams per liter of CrO_3 and 2.5 grams per liter of H_2SO_4 , maintained at 55° C; a current density of 350 amperes per square foot was used.

The data in all except the tensile impact tests indicate that chromium plating appreciably reduces the plastic deformation that can occur in SAE 4130 steel before fracture. Generally, however, the ability of the plated specimens to undergo plastic deformation was substantially increased by baking at temperatures between 100° and 440° C.

Tensile tests were made on specimens plated to nomi-



Percentage elongation as compared with unplated steel is plotted against plating thickness. Triangles represent data for specimens baked 6 to 8 hours at 200° C after plating; the open circles, baked 1 hour at 440° C after plating; and the closed circles, tested without baking.



Cross sections of specimens of SAE 4130 steel tubing after failure in a crushing test. (A) Unplated specimen, (B) chromium-plated specimen without baking, (C) chromium-plated specimen baked at 200° C. The unplated tube underwent the greatest plastic deformation, while the plated but unbaked specimen broke with almost no deformation.

nal thicknesses of 0.0001 to 0.015 inch, as well as on the unplated specimens. Average values for the tensile properties of the unplated steel were as follows: Tensile strength, 187,300 pounds per square inch; yield strength, 175,900 pounds per square inch; elongation in a 2-inch length, 13 percent; true stress at beginning of fracture, 270,900 pounds per square inch; original area of specimen divided by area at beginning of fracture, 2.088. It was found that the tensile and yield strengths decreased with increasing plate thickness until, at a thickness of 0.015 inch, the values were about 90 percent of those for the unplated steel. Baking at 200° and 400° C did not produce any appreciable change in these properties. Plating to a thickness of 0.010 inch reduced the true stress at beginning of fracture to about 80 percent and the percentage elongation and true strain at beginning of fracture to less than 60 percent of that of the unplated steel. However, the baking of plated specimens at 200° or 440° C appreciably increased the values obtained for these properties.

Tensile impact tests were made with the cooperation of the New York Naval Shipyard. These tests were conducted at room temperature; the striking velocity was 27.8 feet per second. The unplated steel elongated 15.8 percent, absorbing 464 foot-pounds of energy at failure; reduction in area was 55.2 percent. The tensile impact properties of plated specimens were 93 percent or more of those of the unplated steel and were not appreciably changed by baking at temperatures up to 300° C.

Bend tests were made in a universal testing machine on specimens having a diameter (before plating) of 0.500 inch and a length of 10 inches. Although unplated specimens could be bent as far as possible in the machine without failure, specimens plated to a thickness of 0.015 inch failed after they had been bent through an angle of about 40°. On the other hand,

plated specimens baked at temperatures of 200° to 440° C could be bent through angles of 70° to 85° before failure. The moduli of rupture of plated specimens baked at these temperatures were equal to that of the unplated steel.

In crushing tests, specimens machined to close tolerances from heavy-walled tubing were tested either as machined, after plating on the inside and outside surfaces to a thickness of about 0.010 inch, or after plating to this thickness and baking at temperatures between 100° and 400° C. The specimens were tested to failure by compression between the stationary and movable heads of a universal testing machine in which the load was applied along a diameter of the tube. Plating increased the load necessary to crush the specimen by a factor of about 1.2 and reduced the deformation at failure to approximately 9 percent of that of the un-

plated steel. Baking at temperatures of 200° to 400° C increased the load necessary to produce failure about 1.4 times and increased the deformation to about 55 percent of that of the unplated steel.

It is possible that hydrogen deposited with the chromium during plating may be a factor in reducing the amount of plastic deformation that the steel can withstand before fracture. Baking of plated specimens removes hydrogen from the chromium [2] and hence may be expected to increase the ability of the steel to withstand plastic deformation.

[1] For further technical details, see Effect of chromium plating on the plastic deformation of SAE 4130 steel, by Hugh L. Logan, *J. Research NBS* 46, 472 (1951) RP2216.

[2] Physical properties of electrodeposited chromium, by A. Brenner, P. Burkhead, and C. Jennings, *J. Research NBS* 40, 31 (1948) RP1854.

Nodule Method Measures Adhesion of Electrodeposits

A simple, inexpensive method for determining the adhesion of commercial electrodeposited coatings has been recently developed by Abner Brenner and Virginia Morgan of the Bureau's electrodeposition laboratory. The new technique involves the electrodeposition of an adherent, mushroom-shaped nodule on the surface of the coating to act as a grip for the application of a detaching force. The force required to pull off the nodule—together with a portion of the coating—is then obtained on a spring balance in ordinary mechanical units.

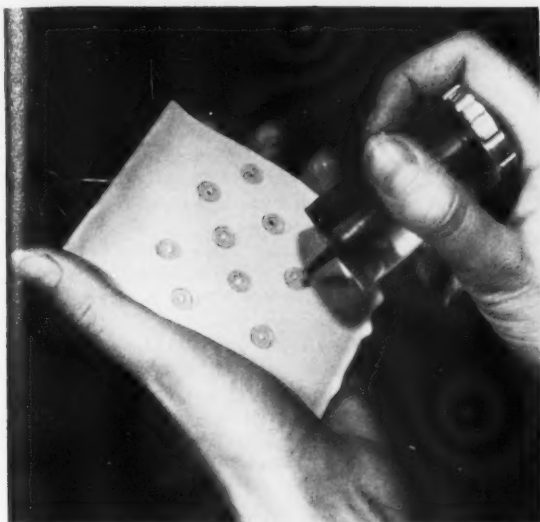


Close up of a nodule used in measuring the adhesion of electrodeposited coatings. The nodule, about $\frac{1}{16}$ inch across its stem, is deposited on the surface of the coating to act as a grip for the application of a detaching force.

The adhesion of an electrodeposit to the basis metal is an important factor in the serviceability of the coating. While very adherent coatings cannot be removed by any ordinary mechanical means, those with a lower degree of adhesion may either peel spontaneously or become detached if the plated object is flexed or abraded. Less adherent coatings are also more susceptible to corrosion, which spreads readily through scratches and imperfections in the surface.

Although a high degree of adhesion can be readily obtained by proper cleaning and pretreatment of the basis metal, very adherent coatings cannot be conveniently and consistently mass-produced without effective laboratory control. Several methods have therefore been suggested for measurement of the adhesion of electrodeposited coatings in commercial production. None of these, however, has been generally applicable. Some, for example, require specially prepared specimens and careful machining. Others involve the application of heat, which may alter the adhesion of the coating. A further disadvantage of some methods is that they do not express the results of the measurement in simple units having any easily visualized significance.

The technique developed by NBS overcomes most of the difficulties associated with the other methods. Perhaps the greatest problem has been that of gripping a thin coating in such a way as to apply a pull sufficient to detach it from the basis metal. This problem was solved by formation of the mushroom-shaped projection on the coating under study. First, all of the plated surface is covered with a lacquer or "stop-off". Then several small areas, about $\frac{1}{16}$ inch in diameter are defined by plastic washers having tapered holes. The lacquer is removed from these small areas, and the nodules are built up by plating the uncovered areas in a cobalt solution. After removal of the plastic washers and stop-off material, the nodules are gripped in a



In the nodule method for determining the adhesion of electrodeposited coatings, the plated specimen is first treated with stop-off lacquer, and plastic washers are placed on the surface. Application of heat thickens the coating, holding the washers in place. The lacquer is then removed from the centers of the washers by means of a coring tool (left), and cobalt nodules are electrodeposited in the central areas. The force required to detach the nodule, together with the coating under test, from the basis metal is then obtained on a spring balance (right).

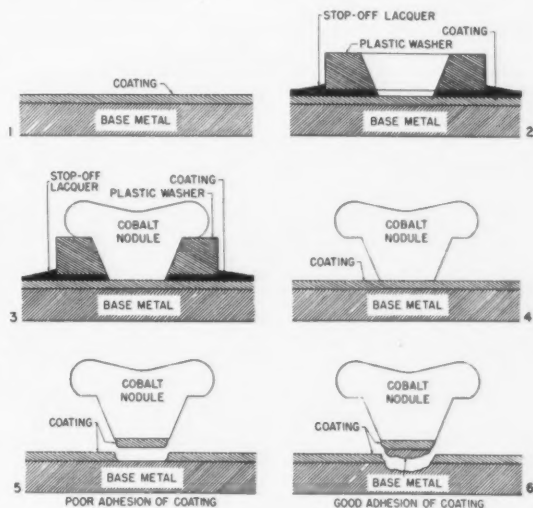
chuck attached to a spring balance and detached by exerting force through the spring. The nodule always removes the initial coating, occasionally along with some of the basis metal if adhesion is high. From the reading of the spring balance and measurement of the area of the base of the nodule, the adhesive force per unit area is computed.

In practice, the plated specimen is first thoroughly cleaned and then dipped in the rack-coating lacquer. After this coating has been partially dried in an oven, the specimen is again dipped in the lacquer, and plastic washers, $\frac{1}{16}$ inch thick and about $\frac{1}{16}$ inch in inner diameter, are placed on the still fluid surface. After the lacquer has been set by heating for 1 or 2 hours, the washers are firmly held in place.

Because the holes in the washers are now filled with lacquer, they must be cut out with a steel coring tool. This should be done carefully as otherwise the nodules will not grow out smoothly, and the cross sections of their bases will not be well defined. In addition to the holes within the washers, two areas on the specimen, 0.5 by 2 inches, are freed from lacquer in order to draw more current and thus make the average current density easier to measure.

The electroplated surfaces exposed through the holes in the washers are scrubbed with pumice or similar material, and the specimen is etched for about 2 minutes in an anodic solution, consisting of either 30-percent or 70-percent sulfuric acid, at a current density of 1.5 amperes per square inch. After etching, the specimen is rinsed quickly and plated—first in an acid solution of cobalt chloride at high current density to secure good adhesion, then in a more dilute solution of cobalt chloride at lower current density to build up the

nodules. The specimen is plated in the acid solution, which contains 100 grams of cobalt chloride dissolved in a liter of dilute hydrochloric acid (10% by volume), for 3 minutes at a current density of 0.5 ampere per square inch. It is then transferred, without rinsing, to the regular cobalt plating solution, a molar solution of cobalt chloride kept at a temperature of 167° F and a



Areas where nodules are to be deposited (1) are first defined by means of plastic washers and "stop-off" lacquer (2). Nodules (3, 4) are built up by plating in a cobalt solution. The force required to detach the plated coating (5, 6) is then measured.

pH between 4 and 5. A current density between 0.13 and 0.65 ampere per square inch is used to form the nodules. Nodules have been built up in as little as 3 to 6 hours by using high current densities, but the strongest and most regularly shaped nodules are obtained by plating overnight at a current density of 0.13 ampere per square inch.

Before measuring the adhesion of the nodule, the plastic washers and stop-off material are removed from the surface. Sometimes the lacquer may be peeled from the specimen, particularly when the coating has been baked at a low temperature. If not, the washers and stop-off may be dissolved or softened in a suitable solvent. The nodule is then gripped in the jaws of the chuck, and the force indicated by the spring balance when the nodule is detached is read.

In order that the results of the test may be expressed in pounds per square inch, the area from which the nodule was detached must be determined because this area may differ somewhat from the nominal area of the hole in the plastic washer. A gage made of transparent

material and containing a series of circles of varying diameter has been found to estimate the area with sufficient accuracy.

The adhesion that can be measured by the NBS method is limited only by the strength of the cobalt nodule. As electrodeposited cobalt has a tensile strength of about 75,000 pounds per square inch, the test should be satisfactory for measuring adhesion of most commercially plated coatings. So far it has not been possible to measure the adhesion of bright nickel coatings because the cobalt nodule does not adhere tenaciously enough to the bright nickel. However, NBS is now making efforts to devise a procedure for obtaining the necessary degree of adhesion. Another possible disadvantage is the time which a skilled technician must spend in making the test. Ordinarily, if the nodules are deposited overnight, one skilled operator can prepare and test about 10 specimens each day.

For further technical details, see The nodule method of measuring the adhesion of electrodeposited coatings, by Abner Brenner and Virginia Dare Morgan, *Proc. Am. Electroplaters' Soc.* **37**, 51 (1950).

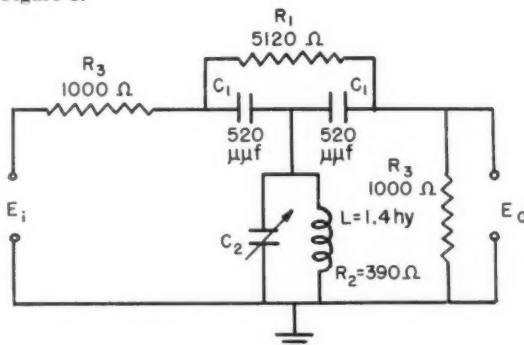
Bridged-Tee Phase Modulators

An electrical network frequently encountered in practice is the lattice, which is often designed to serve as a null network. The equivalent bridged-tee circuit is also widely used for the same purpose. Recently, Dr. M. G. Pawley of the National Bureau of Standards has derived several circuits—very similar in appearance to those commonly used as null networks—that are designed so that the phase of an applied sinusoidal voltage is shifted through a wide range by a variation in but one of the circuit elements and without a change in attenuation. Bridged-tee phase modulators, as the networks are called, have been successfully used in circuits related to radio telemetering, frequency modulation, servo-mechanisms, and other applications where variable impedance control of phase is required.

Generally, lattice networks that are used for variable-resistance or variable-reactance control of phase require push-pull circuits symmetrical to ground and simultaneous variation in two circuit elements to produce phase modulation. Many of these circuits do not permit grounding one side of the input or output or one end of the controlling impedance. A serious limitation of some networks is the change in attenuation accompanying phase modulation, corrective measures often taking the form of amplitude limiters which follow the phase modulating network. In addition, many networks cannot be loaded appreciably.

The bridged-tee phase modulators overcome all of these restrictive characteristics of networks. Wide-range phase shift with constant attenuation is achieved by variation in a single control impedance. In one version, the circuit may be adapted for voltage control of phase, thus providing a simple and highly stable phase modulator useful in radio communication. The circuits function with a common ground and have the ability to work into low-resistance loads.

Figure 1.



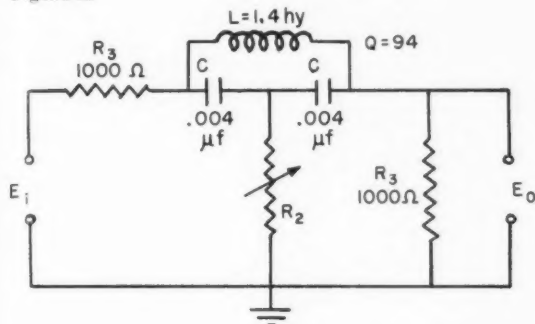
The modulator circuit shown in figure 1 is designed to obtain a phase shift by varying either the capacitance, C_2 , or the frequency. With the values of the circuit components as shown and an operating frequency of 4,170 cycles, the circuit attenuation remains constant at 16 decibels, and the phase shifts 90° as C_2 is varied from zero to 25 micromicrofarads.

With C_2 made equal to zero the bridged-tee network of figure 1 functions as a frequency discriminator. As the input frequency is varied from a few cycles per second to approximately 8,000 cycles per second, the phase shifts nearly 360° while the attenuation remains constant. The phase characteristic is quite linear in the neighborhood of the center frequency.

If in figure 1, $R_1 = 114$ ohms, $R_2 = 1.75$ ohms, $R_3 = 50$ ohms, $C_1 = 10.5$ micromicrofarads, and $L = 1.44$ microhenries, and the circuit is operated at a frequency of 29.1 megacycles, the phase may be shifted by varying C_2 . The attenuation remains constant at 12 decibels.

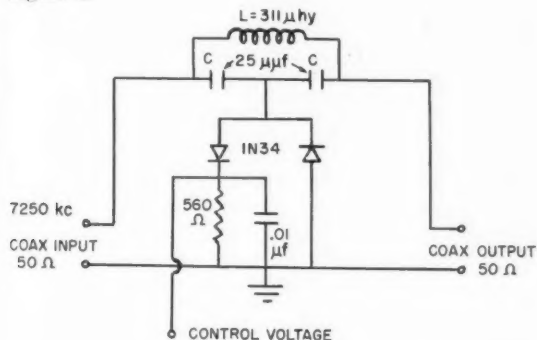
and the phase shifts 135° as C_2 is varied from zero to 5 micromicrofarads. A variation of only 2 micromicrofarads in C_2 results in a 90-degree phase shift.

Figure 2.



Phase shift is produced in the bridged-tee network shown in figure 2 by a variation in the resistance R_2 . At a frequency of 4,170 cycles per second, the attenuation of the circuit is constant at 30 decibels; and when R_2 is varied from zero to 10,000 ohms, the resulting phase shift is about 120° .

Figure 3.



In figure 3 the variable phase-controlling resistor R_2 of figure 2 is replaced by a varistor including two germanium diodes; consequently, a variable input control voltage modulates the phase. Static tests at 7,250 kilocycles indicate excellent linearity of phase versus bias voltage over a 90-degree phase shift. The nonlinear characteristic of the biased varistor compensates for the nonlinear phase characteristic of the bridged-tee network, resulting in a remarkably linear phase response over the 90-degree range. As in the other forms of the network, the modulation is effected with no change in attenuation.

In the circuit of figure 1, in which variable capacitance is the phase controlling element, the following formulas apply

$$\frac{E_o}{E_i} = -\frac{R_3}{4(R_3 + 2R_2)} e^{-j2\theta}$$

where

$$\theta = \arctan \frac{X_{C_1} \delta_e}{R_3 + 2R_2}$$

provided

$$\delta_e = \omega^2 L C_2 \ll 1, Q \gg 1, X_{C_1} \gg R_1$$

$$X_L = \frac{X_{C_1}}{2}$$

and

$$\frac{R_1}{2} = R_3 + 4R_2$$

If L or the frequency is considered as the phase-controlling variable in figure 1, the following formulas

apply

$$\frac{E_o}{E_i} = -\frac{R_3}{4(R_3 + 2R_2)} e^{-j2\theta}$$

where

$$\theta = \arctan \frac{2X_L - X_{C_1}}{R_3 + 2R_2}$$

provided

$$X_{C_1} \gg R_1, C_2 = 0,$$

and

$$\frac{R_1}{2} = R_3 + 4R_2$$

The following formulas are applicable to the circuits of figures 2 and 3, in which variable resistance is the controlling element.

$$\frac{E_o}{E_i} = j \frac{R_3}{4X_C} e^{+j2\theta}$$

where

$$\theta = \arctan \frac{X_C}{R_3 + 2R_2}$$

provided

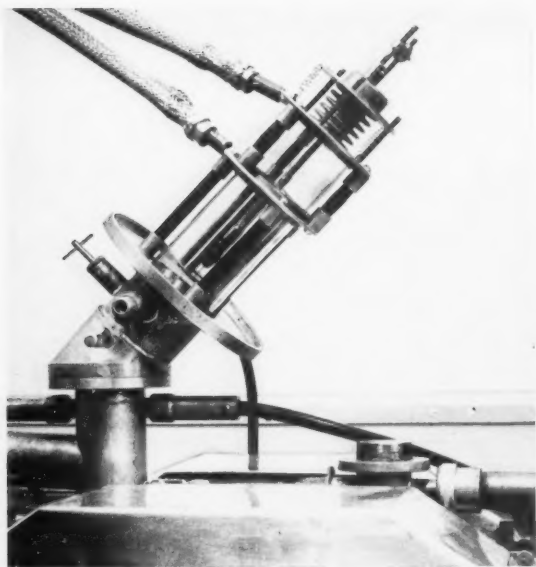
$$Q \text{ (inductor)} \gg 1,$$

and

$$X_L = 4X_C \gg 2R_3$$

The bridged-tee phase shifting circuits were developed originally for use with variable-resistance or variable-reactance telemetering pickup devices to produce phase modulation in multiplex time-division telemetering systems and frequency modulation in multiplex-frequency-division telemetering systems. The network using voltage-control of phase (fig. 3) has proved successful as a phase-modulating unit inserted in the coaxial coupling between low-level stages of a frequency-modulated high-frequency transmitter. In general, this bridged-tee phase modulator should be used in low-level applications in which the relatively high attenuation does not incur a serious power loss.

For further technical details, see Wide-range phase control with constant attenuation by adjustable impedance in a resistance-loaded bridged-tee network, by M. G. Pawley, J. Research NBS 45, 193 (1950) RP2123.

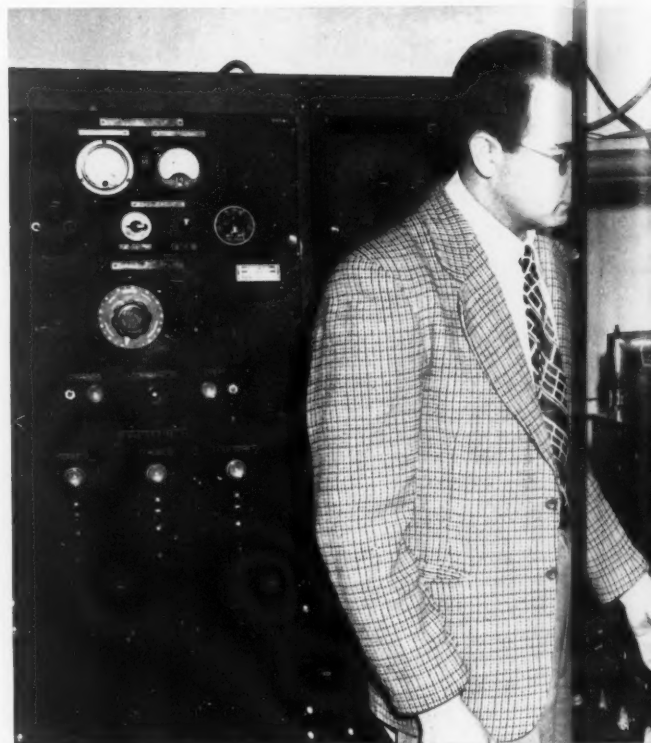


In the modified mass spectrometer used by NBS for the analysis of solids, ions are produced within the glass tube (center) by means of a vacuum spark using a rod of the sample material. After electrostatic deflection through a 45-degree angle, the ions enter the field of the large magnet below. Here the magnetic field causes the ions to travel in vertical circles whose radii depend on the ionic mass, charge, and strength of the magnetic field. The final ion collector is visible at the right end of the magnetic gap. The vacuum spark was first applied in mass spectroscopy by H. A. Dempster of the University of Chicago.

A simple, practical technique now makes it possible to apply the mass spectrometer to the quantitative analysis of solids. Developed by J. G. Gorman, E. J. Jones, and J. A. Hipple of the National Bureau of Standards, the new procedure yields highly accurate, easily interpreted results with much greater speed and convenience than chemical methods. It thus offers a new approach in a number of important fields. For example, the NBS method is expected to be of value in the development and study of new alloys for special uses, in research on semiconductors, and in the analysis of ores for detection of critical materials. As a means of rapid analysis in the control of manufacturing processes, the technique should eventually result in more economical production of a number of important commodities such as steel and other metals.

In the mass spectrometer, materials to be analyzed are first converted into positive ions. The ions are then passed through crossed electrostatic and magnetic fields, where they are deflected by varying amounts depending on their mass and charge. The intensities of the separated ion beams are detected either photographically or electrically and are used to determine the quantity of each material present.

During the past 10 years the mass spectrometer has been applied with outstanding success to the rapid analysis of complex gas mixtures in research and in-

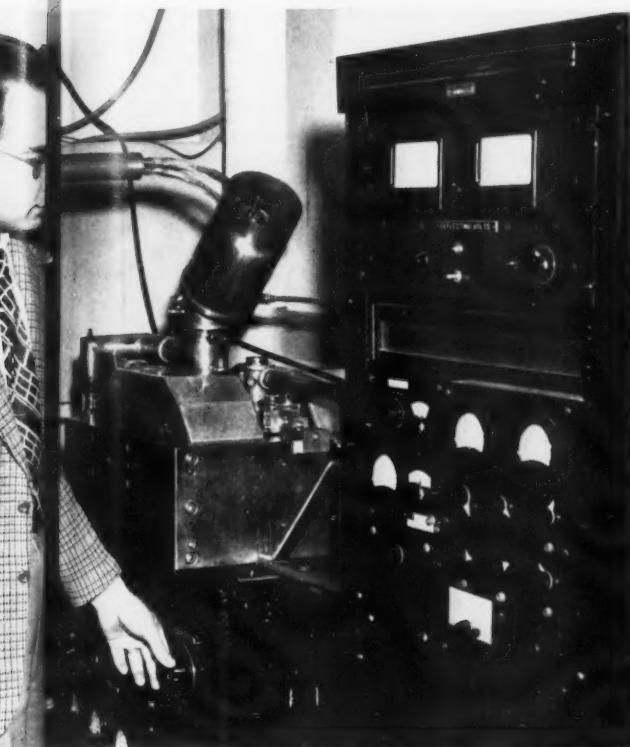


Apparatus developed by the National Bureau of Standards yields highly accurate, easily interpreted results with much speed. The apparatus is of value in the development of new alloys and in controlling processing.

dustrial laboratories. As a result, considerable interest has developed in its possible application to the analysis of solids, particularly metals. However, until now, none of the existing techniques has been found suitable. The best available source of ions from solid materials is the vacuum spark, but the great variation in the intensity of the ion beam thus produced has restricted the spark source to methods employing photographic detection. Such methods are inherently limited in accuracy, convenience, speed, linearity of response, and range of concentrations that may be covered in one exposure. Moreover, the sensitivity of the photographic plate decreases for heavier masses. These difficulties are minimized in the NBS technique, which greatly reduces the effect of variations in the ion-beam intensity and thus makes it possible to use the spark source with electrical detection.

In the NBS method, a monitoring collector placed in the path of the unseparated ion beam provides a measure of the total ions of all masses that are given off by the spark source at any instant. After separation, the currents due to ions of different masses are measured,

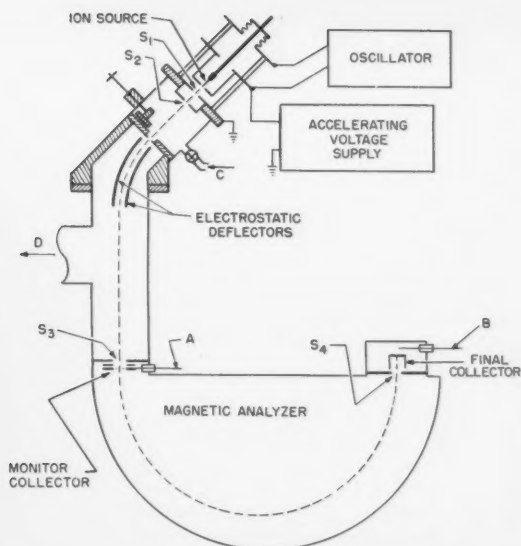
Time Mass Spectrometer



analysis of solids in a mass spectrometer. The new procedure is much faster than chemical methods. The NBS method is expected to control processing of important commodities such as steel.

and a pen-and-ink recorder records the ratios of each of these ion currents to the total ion current measured by the monitoring electrode. Since the total and the partial ion currents tend to fluctuate in the same manner, the ratio obtained on the recorder will be constant for as long as their concentration in the sample does not change.

Ions are obtained by using a rod of the sample material as one electrode in a vacuum spark discharge and are separated according to mass in a modified mass spectrograph of the Dempster type. In this instrument, the ions from the source are first accelerated through a pair of limiting slits by the application of a large potential difference. They then enter an electrostatic field, where each ion is deflected through an angle of a magnitude depending on its individual velocity; this permits only those ions in a narrow energy band to pass through the slit at the entrance to the magnetic analyzer. Within the analyzer a uniform magnetic field perpendicular to the electrostatic field causes the ions to move in a circular path toward the terminal slit and the final collector. The radius r of the circle



The ions are accelerated through slits S_1 and S_2 and then deflected through a 45-degree angle by electrostatic deflectors. Only those ions in a narrow energy band pass through slit S_3 to enter the magnetic analyzer where they travel in a circular path. For a given value of the magnetic field but one type of ion will pass through slit S_4 and enter the final collector. The monitor collector is connected at A to an automatic recorder through a direct-current amplifier. The final collector is connected at B to the same recorder through a second amplifier. Vacuum connections are at C and D .

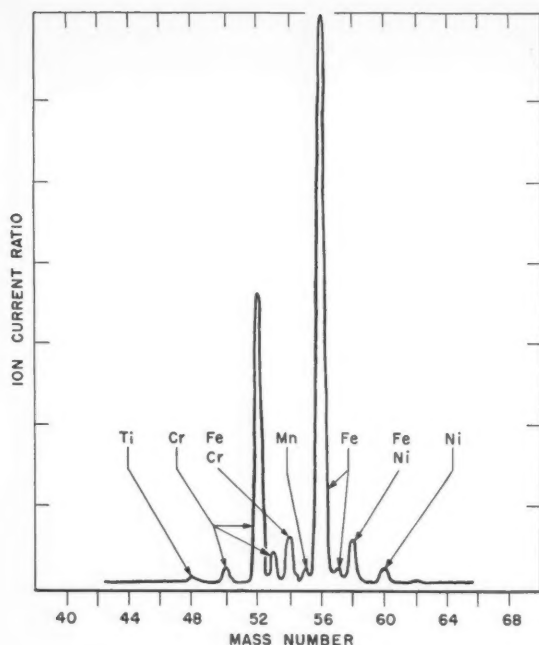
in which an ion of a certain kind must travel is determined by its velocity v , its mass M , and its charge E , as well as the intensity of the magnetic field H , according to the equation

$$HEv = \frac{Mv^2}{r}$$

For given values of E/M and the accelerating potential, the value of r , and therefore of the current registered by an electrometer connected to the final collector, depends on the applied field H .

In the NBS method, the magnetic field is varied so as to sweep ions of different masses across the exit slit of the magnetic analyzer. The measured ion currents are amplified, and the automatic recorder records the ratios of the currents at the final ion collector to the current at the monitoring collector. From the measured value of the magnetic field and the other constants of the apparatus, the mass number corresponding to each ion beam is found. Then, when the ion-current ratios are plotted against mass number, sharp peaks are obtained corresponding to the ions of different masses present in the sample.

In general, an ion-current peak for a given mass number will account for only a part of the total amount of the corresponding element present in the sample; other isotopes of the element having different mass numbers will normally be present. Tables of isotopic abundance are therefore used to adjust the ion current



Mass spectrum obtained from the new method for the analysis of solids. Constituents of the sample of stainless steel are immediately evident from the peaks of the curve.

for the most abundant isotope of each element present in such a way as to obtain a value that includes the less abundant isotopes of the element. The concentration of each element in the sample is then obtained by multiplying the adjusted relative ion current by an "ionization factor" for that element. The ionization factor takes into account the variation in ion-creating efficiency of the different elements in the sample as well

as possible preferential sorting in the analyzer. It is obtained originally in the calibration of the apparatus by dividing the relative concentration of a given type of ion in the beam by the relative concentration of the same element in the sample as determined by chemical analysis. This calibration is greatly simplified by the linearity in the response of the apparatus as the concentration of a constituent element increases in the sample.

While the NBS apparatus retains the basic form of the Dempster spectrograph, several modifications were found necessary. For example, the electrostatic deflection was changed from 90° to 45° so that an electron multiplier placed at the exit slit would not be too close to the ion source. The analyzer housing was also revised to allow for the insertion of a rotating fluxmeter into the magnet gap so that ions reaching the final collector could be identified according to their masses. Likewise, to permit the proper mounting and positioning of the monitoring electrode, a new housing was constructed for the region where the ions approach the magnetic analyzer. An interrupted oscillator operating at about 1 megacycle was employed to produce a spark between the sample rod and a tantalum disk.

In preliminary studies of the method at the National Bureau of Standards, the results on samples of stainless steels were found in close agreement with those obtained by chemical analysis. In the least accurate case the maximum deviation for five different measurements was 5.3 percent of the mean value, and in most cases the maximum deviation of values was 3 percent or less. Thus, the accuracy of the method compares very favorably with recent analyses of gas mixtures in mass spectrometers designed for that purpose. It is expected that the NBS technique will also prove feasible for the analysis of nonmetallic solids, though perhaps with less accuracy than in the case of metals.

For further technical details, see Analysis of solids with the mass spectrometer, by J. G. Gorman, E. J. Jones, and J. A. Hipple. *Anal. Chem.* **23**, 438 (1951).

Symposium on Low-Temperature Physics

More than 200 leading low-temperature physicists from this country and abroad attended a Symposium on Low-Temperature Physics held at the National Bureau of Standards in Washington, D. C., on March 27, 28, and 29. The low-temperature meeting was the first of 12 symposia scheduled for the year 1951, which marks the fiftieth anniversary of the Bureau's establishment. Sponsored by NBS in cooperation with the Office of Naval Research, the program was under the joint chairmanship of Dr. Emanuel Maxwell and Dr. John R. Pellam of the NBS low-temperature laboratory.

Because of the many remarkable phenomena that occur at temperatures near absolute zero and the insight they give into the ultimate nature of matter, low-temperature research is today one of the most challenging fields of pure physics. Two subjects of particular interest are superconductivity—the loss of electrical resistance at very low temperatures—and the properties

of liquid helium II, a form of helium existing at low temperatures that seems to constitute a fourth state of matter. While these subjects received major emphasis at the conference, a wide variety of other topics was covered, including low-temperature magnetism, calorimetry, chemical physics, and the design of low-temperature equipment. As low-temperature physics is still in an early stage of development, the 55 technical papers were chiefly concerned with current problems.

The first day was devoted to superconductivity, and the isotope effect, which relates superconductivity to the atomic mass, was the topic of much of the discussion. The recent discovery of this phenomenon at NBS, in combination with independent results obtained almost simultaneously at Rutgers University, revealed the role of lattice vibrations in superconductivity, providing a basic concept for current theories. Results of superconductivity measurements on isotopes at Oxford, Cam-

bridge, Rutgers, and NBS were presented, compared, and discussed. The symposium thus provided a useful orientation for mapping future research in this field.

One of the highlights of the first day was a panel discussion on the theory of superconductivity, which was conducted by Dr. John Bardeen (Bell Telephone Laboratories), Prof. Hans Frohlich (University of Liverpool), and Prof. L. Tisza (Massachusetts Institute of Technology), exponents of the more important theories contending for recognition today. All three theories incorporate the concept of interaction between lattice vibrations and electrons as a fundamental building block. It was agreed that although superconductivity theory is still in a rudimentary stage, the recognition of the importance of lattice vibrations is a significant advance.

Other interesting topics in superconductivity included the superconducting properties of thin films and alloys, thermal conductivity, specific heats, high-frequency behavior of superconductors, and the discovery of new superconductors. The demonstration of a substantially complete Meissner effect in single-phase alloy systems, reported by Prof. J. V. Stout and Prof. L. Guttman (Institute for the Study of Metals, University of Chicago) was of considerable interest. Dr. D. Shoenberg (Mond Laboratory) in a discussion of recent work on superconductivity at Cambridge University, reported the discovery that the elements osmium and ruthenium are superconducting. Since these elements are transition metals, the discovery of their superconducting properties disproves the previously suggested viewpoint that superconductivity is a property of only two groups of elements in the periodic table. Another report from the Mond Laboratory dealt with the work of Faber on supercooling effects and the growth of superconducting nuclei in superconductors.

Results on the anomalous heat conduction of some superconducting alloys were presented by Prof. K. Mendelssohn (Oxford) and by Dr. J. K. Hulm (Institute for the Study of Metals). Prof. Mendelssohn suggests that the results imply a circulation process in superconductors not unlike that occurring in He II, but there is no general agreement on this point as yet. Professor Rudolf Hilsch (University of Erlangen) described experiments on superconducting thin films in which it was possible to control the transition temperature over wide limits by varying the experimental conditions during deposition.

The second day of the symposium was spent on the properties of liquid helium II. The session began with a group of papers on liquid mixtures of He³ and He⁴. Prof. John Daunt and Dr. C. V. Heer (Ohio State University) reviewed measurements of the depression of lambda temperatures in solutions containing up to 89 percent of He³. Transition temperatures as low as 0.2° K in the presence of He³ were described, and agreement was shown with theory based on London's Bose-Einstein hypothesis. The phase diagram for dilute solutions of He³ in He⁴ was reported by Dr. Henry S. Somers (Los Alamos Scientific Laboratory), and a theoretical interpretation was given by Dr. W. Goad

(Los Alamos), also on the basis of a London statistical model.

Of special interest was the announcement by Drs. D. W. Osborne, B. M. Abraham, and B. Weinstock (Argonne National Laboratory) that they had succeeded in solidifying He³. Their results indicate that He³, like He⁴, probably does not have a triple point and that the liquid is the stable condensed phase at absolute zero.

Interesting experimental developments were discussed in the field of "second sound", a wavelike method of heat transfer occurring only in helium II. Dr. D. V. Osborne (Institute for the Study of Metals) reported the measurement of second sound velocities at temperatures as low as 0.10° K, attained at Mond Laboratory by means of adiabatic demagnetization. This work verified the results of an earlier experiment of the same nature performed at NBS, which showed that the velocity of second sound increases drastically below 1° K. The more recent experiments, however, have been carried to much lower temperatures, and the velocity of second sound has been found to approach about $1/\sqrt{3}$ that of the estimated velocity of ordinary sound at these temperatures, in good agreement with Landau's theoretical prediction. A continuation of work on the mechanical detection of second sound was reported by Dr. J. R. Pellam and W. B. Hanson (NBS). Their measurements now appear to have fully verified the generalized form of Bernoulli's principle, which they previously proposed for liquid helium II to take account of second sound.

Several papers dealt with superfluid flow in helium II and the helium II film. John E. Robinson (Duke University) presented a theoretical paper in which he suggested that the entropy of helium II might be measured mechanically by means of adiabatic oscillations in communicating vessels. Super-flow experiments described by Prof. K. Mendelssohn (Clarendon Laboratory) show new effects that indicate "that a determination of pressure in super-flow requires additional knowledge to the definition of this quantity under classical conditions". Drs. D. C. Henshaw and L. C. Jackson (University of Bristol) described thickness measurements of the stationary helium II film on solids by an optical method that has now been extended to permit measurements as much as 7 centimeters above the liquid helium surface. Dr. J. G. Dash and Prof. H. A. Boorse (Columbia University) reported film-thickness measurements by means of a capacitor depth gage operated at radio frequencies. Heat-capacity measurements on adsorbed films of helium below the lambda point were described by Prof. J. G. Aston and Dr. S. V. R. Mastrangelo (Pennsylvania State College).

An important development in the field of practical apparatus was a new storage container for liquid helium with an evaporation loss of only 1 percent per day. This container, described by Dr. Aaron Wexler (Westinghouse Research Laboratories), should go far in relieving some of the technical problems in the operation of a low-temperature laboratory. Dr. W. E. Henry (Naval Research Laboratory) described some laboratory aids to cryomagnetic research.

The National Bureau of Standards has been active in low-temperature physics since its founding in 1901 and, until World War II, was one of the few laboratories in this country in which low-temperature research was carried on. Over the past 50 years, NBS contributions to the field have included the first successful liquefaction of helium in this country, basic

work on the theory of superconductivity, the first separation of heavy hydrogen, and pioneering research on second sound. Under the sponsorship of the Office of Naval Research, the Bureau is now carrying on a broad program of research on the properties of liquid helium, superconductivity, low-temperature calorimetry and thermometry, and liquefier development.

Fire Tests of Wood-Frame Construction With Asbestos-Cement Facing

Fire-endurance limits for wood-framed walls and partitions with asbestos-cement facings have been established through fire tests at the National Bureau of Standards. The tests of partitions sheathed with gypsum boards over which $\frac{3}{16}$ -inch asbestos-cement sheets were applied gave the best results in this series. Such construction with $\frac{3}{8}$ -inch gypsum board gave a fire-resistance rating of 1 hour, and withstood the hose-stream test after 45 minutes fire exposure. Similarly, a partition with $\frac{1}{2}$ -inch gypsum-board sheathing, and faced with $\frac{3}{16}$ -inch asbestos-cement sheets, provided a rating of $1\frac{1}{4}$ hours as a load-bearing wall, or $1\frac{1}{2}$ hours as a nonload-bearing wall.

The partitions with facings of asbestos-cement sheets over gypsum-board sheathing had somewhat greater fire resistance (as determined from limiting rise of temperature on the unexposed face) than partitions with gypsum lath and plaster facings of approximately the same thickness, whose fire resistance had been previously established. As an example, a section of a partition made with $\frac{3}{16}$ -inch asbestos-cement sheets over $\frac{1}{2}$ -inch gypsum board did not reach a limiting rise of temperature in a fire exposure of 1 hour 30

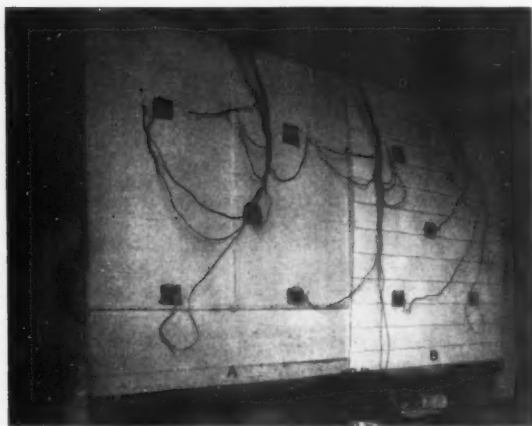
minutes, while partitions with plaster facings over several types of gypsum lath, and having a total lath and plaster thickness of $\frac{7}{8}$ inch on each side, attained limiting temperature rise in times ranging from 47 minutes to 1 hour 29 minutes.

The performance of the combination of asbestos-cement sheets as an outer protective covering on gypsum board gives a considerably better fire-resistance rating than the sum of the components alone. The good performance of this combination arises from the high structural and fire-resistant characteristics of the asbestos-cement sheets and the insulating properties of the gypsum boards. Such construction may be expected to demonstrate fire resistance superior to that of gypsum lath and plaster of equal or even somewhat greater thickness. Dry-wall construction of the above type may be added to already existing walls, as in schools, to provide satisfactory fire resistance, without the inconveniences attending the use of plaster.

Mineral-wool fills made decided improvement in the fire resistance of some walls and constructions, particularly with reference to heat transmission. However, construction difficulties, such as the inability to protect properly the edges of the studs, indicate that as a practical matter the mineral-wool batts cannot be relied on to give adequate protection.

The fire-resistance ratings for the walls and partitions were determined in the Bureau's panel furnace. A fire-resistance rating is defined as the time in hours or minutes that the construction will resist fire as measured in one of the following ways: (1) the time required for fire to break through the specimen; (2) the time during which the average temperature (at five or more specified locations on the outer surface) rises 250 degrees F above the starting temperature; (3) the time when any point on the outer surface reaches 325 degrees F above the starting temperature; or (4) the time that failure occurs under load. Walls or partitions, after a specified period of exposure to fire, must also withstand the impact and erosive effects of a fire-hose stream and prevent its break-through, in order to qualify for a fire-resistance rating of 1 hour or more.

The test walls and partitions were divided into two equal sections, 8 feet long and $10\frac{1}{3}$ feet high, providing ratings on two types of construction from each test. The walls were placed in the panel furnace so as to expose the shingled side of one section and the interior facing of the other. Both sides of the partitions were



Unexposed face of an asbestos-cement faced wall after 42-minutes fire endurance under load in the panel furnace (note jacks). Mineral wool fill weighing 1.05 pounds per square foot was used, and edges of the wall studs were lined with 4-inch by $\frac{3}{8}$ -inch gypsum-board strips before the two types of facings were applied. Section A failed after a 51-minute fire exposure and section B after 42 minutes.

faced with asbestos-cement sheets. However, the sections differed slightly in their internal construction.

Four partitions had fills of mineral-wool batts placed between the studs after the facing sheets had been applied to one side. With the exception of the two sections of one partition and one section of each of two others, protective materials consisting of strips of asbestos paper, gypsum board, or gypsum-board sheathing were nailed to the edges of the studs before the asbestos-cement sheet facings were applied. The asbestos-cement sheets were drilled for nailing. In most tests, the nail heads were countersunk and, in some cases, covered with putty.

The fire-endurance limits of the walls ranged from 32 minutes for the one with asbestos-cement insulated sheathing to 79 minutes for the one whose studs were lined on either side with 1/2-inch gypsum board and the space between filled with two layers of mineral-wool batts. A wall of the latter construction failed in the hose-stream test after 38-minutes exposure to fire; however, failure in this instance was attributable to the technique used in the nailing of the asbestos-cement sheet facing to the studs.

The fire-endurance limit of an uninsulated wood-stud partition faced on both sides with asbestos-cement sheets was 9 minutes. Flame broke through at 27 minutes, and failure under load occurred at 35 minutes. Mineral-wool batt filling between the studs, weighing 1 pound per square foot, increased the fire resistance under load to 40 minutes and time of failure by rise of temperature to 42 minutes. A partition of this type failed to meet the requirements of the hose-stream test after 30-minutes exposure to fire.

A nonload-bearing partition with 3/8-inch gypsum-board strip lining on the edges of the studs and filled between with two layers of mineral wool batts passed the standard 60-minute fire test and, on continuation of the test, failed after 79 minutes; one point on the surface reached 325 degrees F above the initial temperature. This failure occurred on the section having 1.97 pounds per square foot of mineral-wool fill. Corresponding failure of the section having 2.2 pounds per square foot of mineral-wool fill occurred 3 minutes later. The limiting average rise of 250 degrees F (139 degrees C) was reached on one section at 83

minutes and on the other at 91 minutes. A similarly constructed partition met the requirements of the fire and hose-stream test after 30-minutes exposure to fire.

Load-bearing partitions—sheathed with 3/8-inch gypsum wallboard, faced with 3/16-inch asbestos-cement sheets, and tested under load—failed at 62 minutes. The limiting average rise of 250 degrees F (139 degrees C) was reached at 64 minutes. Similarly, a load-bearing partition sheathed with 1/2-inch gypsum boards and faced with asbestos-cement sheets failed at 79 minutes, but the limiting temperature rise had not been reached at the termination of 90-minutes fire exposure. Both of these constructions met the requirements of the hose-stream test after 45-minutes exposure to fire.

Selected fire-endurance limits of wood-framed walls and partitions with asbestos-cement facings

Type of construction	Limits	
	Kind	Time
Exterior walls		
Asbestos-cement insulated sheathing.....		Minutes 32
Lined on both sides with 1/2-inch gypsum board; filled with 2 layers of mineral-wool batts.		79
Interior partitions		
Load-bearing faced on both sides with 3/16-inch asbestos-cement sheets.	Uninsulated.....	Temperature..... 9
		Flame through..... 27
		Load..... 35
	Mineral wool-fill (1 pound per square foot).	Load..... 40
		Temperature..... 42
Load-bearing, faced with 3/16-inch asbestos-cement sheet.		Hose..... 30
	Sheathed with 3/8-inch gypsum wallboard.	Load..... 62
		Temperature..... 64
		Hose after 45 minutes..... Passed
	Sheathed with 1/2-inch gypsum wallboard).	Load..... (*)
Nonload-bearing, stud edges lined with 3/8-inch gypsum board.		Temperature..... 79
	Mineral wool—fill (1.97 pounds per square foot).	
	Mineral wool—fill (2.2 pounds per foot.)	Temperature..... 82
	Mineral wool—fill...	
		Hose after 30 minutes..... Passed

* Temperature limits not reached in 90 minutes.

Ceramic Coatings Prevent Exhaust-Gas Corrosion

An investigation of the corrosive effects of lead bromide vapors on various heat-resistant alloys, both with and without protective ceramic coatings, has recently been completed at the National Bureau of Standards. Lead bromide, which is the principal lead compound present in aircraft exhaust gases, has been suspected of contributing significantly to exhaust-system corrosion. Until now, however, available data bearing on this question have been few and inconclusive. The NBS investigation demonstrates that the uncoated alloys corrode fairly rapidly when exposed to lead bromide vapors at high temperatures, but that certain

ceramic coatings effectively prevent corrosion under the same conditions. Sponsored by the National Advisory Committee for Aeronautics, the studies were conducted by Dwight G. Moore and Mary A. Mason of the NBS enameled metals laboratory.

Lead bromide is present in the exhaust gases of all engines that use leaded gasoline as a fuel. Aviation gasoline is more heavily leaded than automobile fuel, however, and aircraft exhaust temperatures are higher. For these reasons, corrosion from lead bromide is a greater possibility in aircraft than in automobiles. The fact that lead bromide vapors prove corrosive



The small electric test furnace (left) is used for studying the corrosive effects of lead-bromide vapors on alloy specimens with and without ceramic coatings. The lid, from which a number of alloy specimens are suspended, is being lowered into position. Furnace temperature is measured by the portable potentiometer (right) in conjunction with a thermocouple inside the furnace.

under certain conditions does not, of course, mean that leaded gasoline is undesirable as a motor fuel.

The lead bromide found in exhaust gases results from the interaction of tetraethyl lead and ethylene dibromide, the active additives of leaded gasoline. The tetraethyl lead is added to improve combustion characteristics, while the ethylene dibromide acts as a scavenging agent. In this capacity the ethylene dibromide converts the lead oxide, which would otherwise be formed during combustion, into lead bromide. Lead bromide has a considerably higher vapor pressure than lead oxide and is therefore more readily passed through the exhaust system as a vapor.

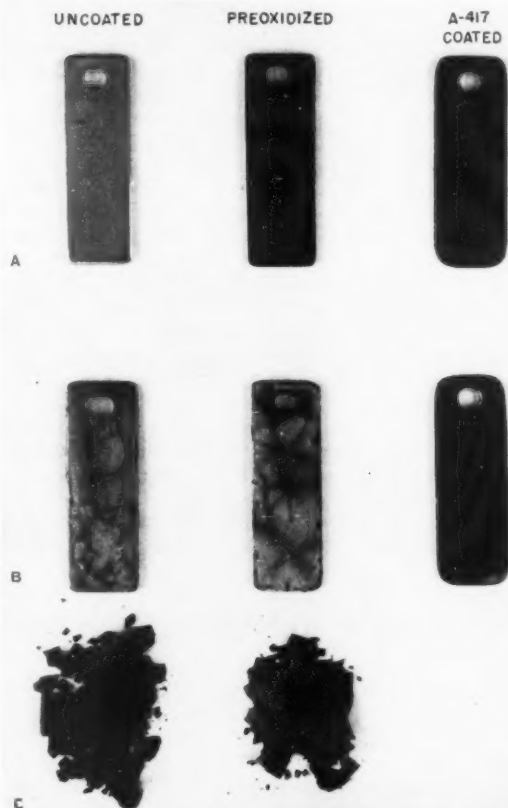
Five heat-resisting alloys were investigated by NBS: Inconel (a high-nickel alloy), types 347 and 19-9DL stainless steels, Vitallium, and S-816. The first three alloys are in regular use in exhaust systems. Vitallium and S-816 are turbine-blade alloys and, although too expensive for general exhaust-system use, could be used for small critical parts. Specimens of each alloy with five different coating conditions were studied: an uncoated specimen, a preoxidized specimen, and three ceramic-coated specimens. The ceramic coatings, all commercially available, were NBS types A-417, A-19, and A-520. Specimens were exposed to lead bromide vapor for periods up to 6 hours in an air atmosphere at temperatures of 1,350°, 1,500°, and 1,650° F.

In the NBS investigation, a small furnace was first preheated to the desired temperature. After temperature equilibrium had been reached, the lid was removed and a 1-gram charge of chemically pure lead bromide was dropped into the furnace. A second lid, from which eight alloy specimens were suspended, was then quickly put into position. This lid fitted loosely and

allowed some air to diffuse into the furnace. Determination of the effectiveness of the ceramic coatings did not require that the lead-bromide vapor concentration be kept constant.

Each batch of specimens was heated in the furnace for a total of 6 hours. At 1-hour intervals, however, the specimens were removed, examined, and then replaced together with a new charge of lead bromide. This hourly examination included cleaning of a limited area of the specimens—which were in the form of flat strips—and measuring the loss in metal thickness from corrosion. Loss in weight was also measured in some instances. At the end of the tests, cross sections of the specimens were studied microscopically, and both the scale layer and the cleaned alloy surface were examined spectrochemically for lead content.

Large differences in the resistance of the several alloys to attack by lead bromide were found: although all five uncoated alloys suffered corrosion at all test tem-



Uncoated, preoxidized, and ceramic-coated (A-417) specimens of type 347 stainless steel are compared (A) before treatment and (B) after a 6-hour lead-bromide-vapor treatment at 1,650° F. A substantial amount of scale (C) dropped off the uncoated and preoxidized specimens after treatment. The ceramic-coated specimens were unaffected except for slight flaking near the edge.

temperatures, the loss of thickness in the full 6-hour period ranged from 1.2 to 10.1 mils. Alloys S-816, Vitallium, and Inconel were notably more resistant than the 19-9DL and type 347 stainless steel, both of which are high-iron, austenitic-type alloys. Microscopic examination indicated that a selective attack took place with the 19-9DL and 347 steels, leaving a spongy layer near the surface. With the other alloys, however, very little selective penetration was found.

Preoxidation of the surfaces of the alloys tended to retard corrosion for the first hour or two only, after which corrosion proceeded at an undiminished rate. Preoxidation was accomplished by heating specimens in air for 4 hours at the test temperature.

No consistent relation was found between temperature and rate of corrosion; some but not all of the alloys showed less corrosion at the higher temperatures. Similar results have been reported by other investigators of alloy corrosion and are apparently not unusual. However, it must be remembered that in the NBS test method the lead bromide concentration probably dropped off more rapidly with time at higher temperatures than at lower temperatures. Thus at 1,650° F a 1-gram charge of lead bromide may have left the furnace as vapor in a few minutes, whereas at the lower temperatures a 1-gram charge probably fed vapor into the furnace atmosphere throughout the entire 1-hour heating period.

Loss in thickness under various test conditions^a

Alloy	Coating	Loss in thickness		
		1,350° F	1,500° F	1,650° F
		Mils	Mils	Mils
Inconel	None	1.6	6.2	1.6
	Oxide	0.9	4.4	1.5
	A-417	.4	0.3	0.4
	A-520	0	0	.6
	A-19	0	0.2	.4
Type 347	None	9.1	9.8	8.4
	Oxide	8.4	8.9	10.8
	A-417	0	0.2	0.2
	A-520	0.2	.5	.2
	A-19	0	.2	0
Type 19-9DL	None	9.9	10.1	10.2
	Oxide	5.8	8.1	10.7
	A-417	0.4	1.1	1.0
	A-520	0	0.7	0.3
	A-19	0.2	.5	.5
Vitallium	None	3.7	3.5	2.4
	Oxide	2.5	2.2	1.5
	A-417	0.1	1.0	0.3
	A-520	0	0.5	.6
	A-19	0.2	.6	.5
S-816	None	1.2	6.6	2.5
	Oxide	1.9	6.3	2.1
	A-417	0	0.5	1.0
	A-520	0	.6	0.9
	A-19	0.4	.8	.8

^a Figures are for losses in thickness of the various alloys with and without coatings after 6 hours at the indicated temperature in an air atmosphere containing lead-bromide vapor.

^b Average of 6 specimens; all other figures are averages of 2 specimens.
^c Microscopic examination of cross sections of ceramic-coated specimens indicated no loss of thickness. Losses recorded for the coated specimens can be attributed to the light sandblast treatment needed to remove the coating preliminary to micrometer thickness measurements. Decrease in alloy thickness from the sandblasting was investigated and found to be less than 0.2 mils per sandblasting.

URSI-IRE Meeting at NBS

Over 300 workers in the various fields of radio research assembled in Washington, D. C. for the spring meeting of the U. S. A. National Committee of the International Scientific Radio Union and the Professional Group on Antennas and Propagation of the Institute of Radio Engineers. The sessions were held at the National Bureau of Standards on April 16, 17, and 18 in commemoration of the NBS Semicentennial.

The International Scientific Radio Union, commonly designated URSI, is one of several world scientific unions organized in 1919 under the general sponsorship of what is now the International Council on Scientific Unions. The aims of the Union are to promote the scientific study of radio communications; to aid and organize radio research on an international scale; and to facilitate agreement upon common methods of measurement and the standardization of measuring instruments. The International Union provides an organizational framework to aid in promoting these objectives, although the actual technical work is largely done by the national sections of the various member countries. The U. S. A. National Committee is subdivided into six commissions: Radio Measurement Methods and Standards; Tropospheric Radio Propagation; Ionospheric Radio Propagation; Terrestrial Radio Noise; Extraterrestrial Radio Noise; and Radio Waves and Circuits.

The meeting was under the general direction of Dr. L. V. Berkner (1950 Chairman of the U. S. A. National


International Scientific Radio Union U. S. A. National Committee Organized under National Research Council

Congratulations to

National Bureau of Standards upon the occasion of its Fiftieth Anniversary

In Recognition of the extraordinary service to science, and to the general welfare, rendered by the National Bureau of Standards, throughout the first half of the twentieth century; in appreciation of the firm basis provided by the Bureau through its standardization and research work for advance in radio whose growth from a small beginning has been precisely concurrent with that of the Bureau; and in honor of the Bureau's own valued contributions to the achievements of radio science: the U. S. A. National Committee of the International Scientific Radio Union

Presents this tribute to the Bureau on the occasion of the meeting at the Bureau of the U. S. A. National Committee of the International Scientific Radio Union, April 16 to 18, 1951.



Scroll presented to the National Bureau of Standards by the International Scientific Radio Union in commemoration of the Bureau's Fiftieth Anniversary.

Committee), and Dr. Newbern Smith (NBS) was in charge of the technical program and arrangements. Administrative sessions of the individual commissions were held on Monday morning, April 16. Dr. C. R. Burrows (Cornell University) was elected Chairman; Dr. Newbern Smith (NBS), Vice Chairman; and Dr. A. H. Waynick (Pennsylvania State College), Secretary-treasurer. On Tuesday morning, the technical sessions were opened with a speech by Dr. E. U. Condon, Director of the National Bureau of Standards, in which he described the radio research activities of the Bureau, past, present, and future. At this time, the U. S. A. National Committee presented Dr. Condon with a commemorative scroll in recognition of the Bureau's 50 years of service to science and to the general welfare.

During the 2-day general meeting, 50 outstanding papers were presented in joint and separate specialized sessions. Included in the joint session was a discussion of atmospheric and the propagation of very-low-frequency waves by J. A. Ratcliffe (Cavendish Laboratory, Cambridge, Eng.). Because of the extreme difficulties and expense involved in using low-frequency (below 10 kilocycles) equipment, propagation measurements were made on the low-frequency components of signals generated during thunder storms.

In one of the separate sessions, Mr. R. K. Moore (Cornell University) described the anomalous propa-

gation observed by radio amateurs at frequencies of 28 to 148 megacycles during displays of the aurora (northern lights). In another session, Mr. H. W. Wells (Carnegie Institution of Washington) made an analysis of ionosphere measurements that revealed fluctuations of the F2 region between stations separated by a distance of only 100 to 150 miles. One of the Ionospheric Radio Propagation Commission sessions was devoted almost entirely to discussions and results of the absorption and polarization of low-frequency signals. Most of the work discussed by the Commission on Radio Waves and Circuits was on very-high-frequency and microwave antenna problems, techniques, and theories pertaining to beam synthesis, and analysis of problems in microwave optics.

The effects on propagation of irregular and rough terrain and of changes in the refractive index of elevated layers of the atmosphere were discussed at the session on Tropospheric Radio Propagation. Also included were some experimental results of investigations in VHF and microwave propagation phenomena. Within the field of terrestrial radio noise, papers were presented that described atmospheric noise levels and wave forms. A method for studying radio noise objectively by the use of radio teletype equipment was presented. Techniques for suppression of radio interference were also discussed.

Publications of the National Bureau of Standards

PERIODICALS

Journal of Research of the National Bureau of Standards, volume 46, number 5, May 1951 (RP2205 to RP2211, incl.). Technical News Bulletin, volume 35, number 5, May 1951. 10 cents.

CRPL-D81. Basic Radio Propagation Predictions for August 1951. Three months in advance. Issued May 1951. 10 cents.

RESEARCH PAPERS

Reprints from Journal of Research, volume 46, number 4, April 1951

RP2195. Analysis of symmetrical waveguide junctions. David M. Kerns. 10 cents.

RP2196. Comparison of viscosities of rubbers from the McKee worker-consistometer and from the Mooney viscometer. A. B. Bestul, G. E. Decker, and H. S. White. 10 cents.

RP2197. Spectrophotometric determination of carboxyl in cellulose. Florence H. Forziati, John W. Rowen, and Earle K. Plyler. 10 cents.

RP2198. Static friction tests with various metal combinations and special lubricants. H. S. White and Dino Zei. 10 cents.

RP2199. Apparatus for the preparation of anhydrous titanium (iii) chloride and titanium (iii) bromide. J. M. Sherfey. 5 cents.

RP2200. An apparatus for studying autoignition of engine fuels; results with normal heptane and normal hexane. William J. Levedahl and Frank L. Howard. 10 cents.

RP2201. Creep of high-purity aluminum. William D. Jenkins. 10 cents.

RP2202. Standard X-ray diffraction patterns. Howard E. Swanson and Eleanor Tatge. 10 cents.

RP2203. The half-life of carbon 14. George G. Manov and Leon F. Curtiss. 10 cents.

RP2204. Heat capacity of liquid mercury between 0° and 450° C; calculation of certain thermodynamic properties of

the saturated liquid and vapor. Thomas B. Douglas, Anne F. Ball, and Defoe C. Ginnings. 10 cents.

CIRCULARS

C499 (Supplement 1). Nuclear data (January to July 1950). (First of three supplements that will be mailed automatically to purchasers of Circular 499.) Price, Circular 499 and three supplements, \$4.25.

PUBLICATIONS IN OTHER JOURNALS

A new method for determining the value of the Faraday. D. N. Craig and J. I. Hoffman. Phys. Rev. (57 East Fifty-fifth Street, New York 22, N. Y.) 80, 487 (1950).

Apparatus for determining freezing points at saturation pressure from time-temperature freezing and melting experiments. A. R. Glasgow, Jr., N. C. Krouskop, and F. D. Rossini. Anal. Chem. (1155 Sixteenth Street NW., Washington 6, D. C.) 22, 1521 (1950).

Depolymerization as a chain reaction. R. Simha, L. A. Wall, and P. J. Blatz. J. Polymer Sci. (215 Fourth Avenue, New York 3, N. Y.) 5, 615 (1950).

Analysis of solids with the mass spectrometer. J. G. Gorman, E. J. Jones, and J. A. Hipple. Anal. Chem. (1155 Sixteenth Street, NW, Washington 6, D. C.) 23, 438 (1951).

Coulomb wave functions expressed in terms of Bessel-Clifford and Bessel functions. J. Math. and Phys. (Massachusetts Institute of Technology, Cambridge 39, Mass.) 29, 303 (1951).

Natural and synthetic rubbers. Norman Bekkedahl. Anal. Chem. (1155 Sixteenth Street, NW, Washington 6, D. C.) 23, 243 (1951).

El sistema I. C. I. para la especificacion del color. Deane B. Judd. Anales de la Real Sociedad Espanola de Fisica y Quimica (Madrid, Spain) 46, 123 (1950).

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